Student Preferences in Networking Education

An Honors Thesis (HONR 499)

by

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Muncie, Indiana

May 2015

Expected Date of Graduation

May 2, 2015

Abstract

Data networking instructors experience the challenge of giving students the lab environments that allow them to best apply and continue their learning. This is generally done using three different environment options: physical hardware, remote labs, and simulation software. Each different type of environment provides its own benefits and obstacles. The high cost and limited accessibility associated with both physical hardware and remote labs are major obstacles for a student's learning. Simulation software provides better accessibility, but not full configuration compatibility. I will address many of the main benefits and drawbacks of each system and also present the preliminary results of a student survey about preferences in their networking education lab environments.

Acknowledgements

I would like to thank Dr. David Hua for advising me through this project. His help guiding me through this process pushed me to keep on track and finish with a project that I am pleased with. I sincerely could not have finished without his support.

Project Rationale

Student Preferences in Networking Education: Project Rationale

Keeping students engaged and interested in their education can be a challenge for instructors, no matter what type of field they are in. In order for the students to be able to effectively learn the materials, they need a combination of a strong conceptual understanding of the materials along with the ability to apply their learning in a hands-on environment. In many cases, there is more than one way to create a learning environment in order for these students to apply their knowledge. The challenge that instructors are facing is in the choice between the different options to teach the students.

It is important in every different field of learning to take into account what students feel is the most beneficial to their education. As a student studying computer technology, I am surrounded every day with different types of learning environments. With my major, there are many different options that can be used to teach the materials, and I have had the opportunity to work with all of them. Each learning environment has its own set of benefits and drawbacks, and each is effective in applying the concepts that are taught in classroom lectures.

The question that I am posing is: Which method of teaching networking is the most beneficial to the students? I don't feel that this question can be answered by instructors alone. In order to gain the best possible insight, the students who are learning this material must be asked. In order to do this, a survey was set up asking questions about each of the three different methods used in networking education. The preliminary results from the survey are explained in the article, and all responses are presented within this project.

This thesis is designed to be in the form of a research article. This article is intended to be further expanded upon and then sent to various technology journals for possible publication. Being able to share the findings of this research with other instructors in networking could help

to inform them on how the students that they will be teaching prefer to learn the materials. In turn, this article would then be able to benefit each of the students studying in this field by helping to providing them with the most beneficial environment for their education.

In order to help spread the interest of student preferences in their education and to gain some insight into other viewpoints about the topic, I participated in the Student Research Symposium here at Ball State University. The symposium allowed me an opportunity to present some preliminary results from the study to the public and get more opinions from people who are not so familiar with the subject. Even though my study focuses on networking education in particular, people were able to relate to the base idea of the study. There are different ways of teaching students in nearly every field available. Input from the students is what should be feeding the decisions about what teaching methods are used. The poster that was used for the symposium is included in this project.

Students should be able to have access to the most beneficial learning environment that they possibly can. In order to determine what the best environment for the students is, it is important to ask the students because they are the ones who will be using it. Students tend to be more engaged and willing to lean when their classroom learning experience relates closely to what they will be doing in their future careers. When students are more able to engage in and relate to their educational experience, the better prepared they are for their careers outside of school. This, in turn, will help to improve the quality of the workforce in the future.

Article

Student Preferences in Networking Education

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Abstract

Data networking instructors experience the challenge of giving students the lab environments that allow them to best apply and continue their learning. This is generally done using three different environment options: physical hardware, remote labs, and simulation software. Each different type of environment provides its own benefits and obstacles. The high cost and limited accessibility associated with both physical hardware and remote labs are major obstacles for a student's learning. Simulation software provides better accessibility, but not full configuration compatibility. I will address many of the main benefits and drawbacks of each system and also present the preliminary results of a student survey about preferences in their networking education lab environments.

Teaching Networking Education

Data networking is the base upon which other technology systems are built. The students who are learning how to create and use these systems require access to learning environments that will allow them to personally work with the technology. In addition to lecture and studies about the materials, students need to be able to experience working with the actual systems in order to be the most prepared possible for their future. Networking education environment opportunities are broken into three general categories of systems: physical hardware, remote labs, and simulation software. Each different method of education comes with its own benefits

and drawbacks. The struggle that instructors face is finding the solution that is able to give the students the learning environment that they feel best prepares them for the workforce and also in being able to implement and maintain that system.

Physical Hardware

There is always a challenge in providing students with the proper environment to best foster their learning. Ideally, instructors would be able to provide the most realistic environment possible in order to best prepare the student for the real world. This would require labs to be equipped with an abundance of every type of equipment that is used in networking, such as switches, cables, computers, and routers. The use of physical hardware in a student's education gives them the ability to work hands on and see how the concepts that they are learning in lectures actually apply to the equipment and the real world. However, there are drawbacks to using physical hardware in classrooms, the main one being the steep cost (Lawson & Stackpole, 2006).

Networking equipment is expensive, and using it in a classroom environment requires there to be many multiples of each piece of equipment so that all students are able to have access to the hardware. Even if a lab environment can be created to be fully stocked and functional for all students to have access to, new technology is always being developed. Eventually, the equipment in the lab will become out of date and need to be replaced, which brings about the same extensive cost that there was in the initial set up of the lab. There is also the ever present chance that the equipment will fail or break, causing more cost to fix or replace the equipment. This can also cause disruption to students who may have been relying on the equipment.

Students work on projects and build their own networks for class assignments. Depending on the size of the program, the number of classes using the equipment, and the amount of students taking classes, there can often be competition for use of the hardware. Different classes will each require access to the equipment to work on separate classwork and open lab hours for students are not always plentiful. This means that accessibility to the equipment for the students is extremely limited (Ma & Nickerson, 2006). If students are not able to finish a lab or a project during their class time, they are obviously not able to take the equipment home with them to continue working. The students end up competing with each other for use of the equipment or are sometimes unable to complete their work because they did not have enough access (Hua, 2013).

Physical equipment is able to give students a real look into the environments and equipment they may be working with after graduation in the work force. It is the best way to teach the students the real materials, but it is hard to obtain and manage a learning environment of physical hardware. Being able to set up an environment for students to learn with that will mimic what they will be doing in the future as closely as possible should be the goal in every situation. Ultimately, using physical hardware for a student's education would be the most beneficial method.

Remote Labs

Remote labs allow students to connect to physical equipment using an internet connection instead of having to be directly connected to the equipment (Lindsay & Good, 2005). This way, students are still able to get the benefits of using the physical equipment without being limited to only the time that the lab is available for use. Remote labs allow connectivity from anywhere

with an internet connection and the proper equipment (Border, 2007). The Cisco Networking Academy offers the NetLab Academy Edition in support of its networking curriculum (Cisco Networking Academy, 2007). NetLab and other systems like it offer students a way to get the same experience of working with real equipment with better accessibility.

In order to implement a remote lab system for students to use, there is a hefty cost. There will be a cost for the software and equipment needed to run the remote lab system in addition to the cost of all of the same physical hardware used in physical labs. This means that implementing a remote lab environment could be significantly more expensive than just using the physical hardware alone. Many systems also require an extra cost in order to keep the system up and running, such as an annual maintenance plan.

A major drawback of using a remote lab environment, aside from the cost, is that students are still limited by the times that they are able to access the equipment. Even though all of the equipment can be accessed remotely, there are still multiple classes using the same equipment and many students who are all trying to accomplish their work at once. Only one student or group of students is able to access the hardware at a time to avoid conflicts. There would still need to be some sort of scheduling system put in place so that students are not trying to use the equipment at the same time and interfering with another's work.

Remote labs are able to help begin to solve some of the issues that come along with just using physical hardware, such as accessibility. However, the cost of setting up and maintaining the system along with the continued issues of limited accessibility make the system hard to use in teaching students. They are still able to benefit from the use of the real equipment, but are still not given the full opportunity of using the real hardware whenever they need.

Simulation Software

Simulation software provides an opportunity for students to take a virtual version of networking equipment with them wherever they go (Lahoud & Krichen, 2010). The use of simulation software eliminates many of the problems that are associated with both physical hardware and remote labs. There are a variety of different simulation software programs that each have their own benefits and drawbacks.

Simulation software can generally be run on any computer, which eliminates the need for a person to be in the lab in order to do a project or assignment. The software can then be taken anywhere and used at any time by the students to ensure that they have plenty of opportunity to complete their assignments and even work on projects of their own in their free time. Students do not have to rely on the use of school equipment at all in order to complete assignments using simulation software.

One major downside that is seen with simulation software is that there are many premade lab assignments that correspond with the curriculum. While this would normally serve to make an instructors life easier by not having to create their own labs, students are easily able to find answer files online and avoid doing the real work and actually learning the material for themselves. The assignments are able to be changed and edited by the instructors to keep the students from being able to successfully use the answer files, but there are many cases where this is not done. If the lab assignments are not edited, it is very easy for students to complete the assignment using an answer file without actually learn anything from the process.

Certain versions of simulation software have their own additional drawbacks. One type of simulation software, Cisco's Packet Tracer, uses virtual equipment that does not always support all of the possible configurations that are available on the physical equipment. The

students are limited to the use of only the configurations that have been added by the creators of the program. This means that even though the students are able to access Packet Tracer's software for free and take it with them wherever they go, they could still possibly not be able to fully complete an assignment or network design because they are limited by the configurations available on the software.

Other simulation software options, such as GNS3, were created to be open source. This means that students are able to load full operating systems onto the virtual equipment and will be able to have the full range of possible configurations that are available on the physical hardware (S4). There is no limitation on what the virtual devices could do in comparison to the real equipment. The biggest issue with this type of simulation software is being able to obtain the operating systems that would be needed in order to make the virtual equipment in the program work. They can be costly to obtain if not already owned, especially considering the many different types of equipment that will each require its own operating system.

Simulation software is able to bypass many of the issues that arise with using physical hardware or remote labs, such as cost and accessibility. There are programs that are free and can be taken anywhere a student goes. A major issue comes up when we begin to question if this type of environment is real enough to give a student the feel of using physical hardware without having to sit in front of it. In order to keep the students engaged in the work, the simulation software needs to be able to create as real of an environment as possible (Sauter, Uttal, Rapp, Downing, & Jona, 2013). Virtual equipment within this software won't have the same types of failures that physical hardware will have, and even though these issues can disrupt the flow of work, it is able to also give students insight on how to troubleshoot and resolve the issues.

Simulation software is convenient but not always able to give the most realistic environment for a student's education.

Methodology

In order to accurately determine what students most prefer to use as a learning environment, a survey was prepared to be distributed to students who are currently enrolled in the Cisco Networking Academy. The survey asked questions about each of the three types of networking education environments, including which system is preferred and the likes and dislikes of each system. The study was given in order to determine what learning environment the students are finding to be the most beneficial to their education. The working hypothesis is that students prefer the use of physical equipment but are frustrated with the limited accessibility that they have to the equipment, so they fall back on the use of simulation software.

Results

Preliminary results from the survey are shown in the following tables, along with explanations on the answers that were received from the students.

What is your gender?		
#	**Answer**	**Response**
1	Male	55
2	Female	9
	Total	64

Table 1

Table 1 shows the first question of the survey, which serves to gain knowledge about the makeup of the audience that was being surveyed. The majority of those surveyed were male, with significantly less females.

How long have you studied networking?							
Question	**None**	**0 - 6 months**	**6 - 12 months**	**1 - 2 years**	**Over 2 years**	**Total Responses**	**Mean**
How long have you studied networking?	2	5	4	17	38	66	4.27

Table 2

Table 2 displays the results of the second question of the survey, which inquires how long the students being surveyed have been studying networking. This information helps to verify how useful the rest of the survey answers will be. The more experience that each of the surveyed students has with the systems, the more accurately they will be able to answer questions about them.

What forms of technology have you used for networking labs?		
#	**Answer**	**Response**
1	Physical labs: This is when you have a set of hardware devices which you have direct access. For example, being assigned a set of routers and switches you must configure for a lab.	64
2	Remote Labs: This is when you remotely connect to physical hardware through a network connection.	33
3	Virtualization software: This is software that allows you to create and configure network topologies in a computer. Examples include Packet Tracer, GNS3, and Boson NetSim.	55
4	I have not had to do any networking labs.	3

Table 3

The students were next asked which of the three types of networking labs they have had the opportunity to work with, as shown in Table 3. Many students said that they have been able to work with all three types, and even more students had used at least two out of the three forms of technology. If the students answered that they had not had any experience with networking labs, they were then finished with the survey. This ensures that the questions that followed in the survey were accurately answered by students who have actually used the system.

How often have you used physical labs in in your classes?		
#	**Answer**	**Response**
1	Not At All	0
2	Rarely	1
3	Occasionally	9
4	Frequently	22
5	All the time	15
	Total	47

Table 4

Students were asked how often they used physical labs in their courses. As the results show in Table 4, the majority of those students surveyed answered that they used physical labs fairly often.

The following questions are about physical labs. Choose the response that most reflects your opinion.				
#	Answer	Average Value	Standard Deviation	Responses
1	It was easy to work with.	69.41	19.18	46
2	It supported all of the configurations required for my labs.	73.11	22.78	47
3	It helped me understand course readings and lectures.	84.93	15.08	46
4	It helped me prepare for a career in networking.	86.89	18.54	44

Table 5

Table 5 shows the results of questions from the survey that begins to ask students about physical labs specifically. The students were asked to rank on a scale of 1 to 100 how well the statement reflected their opinion about labs using physical hardware. The table shows the average value of the student's answers to give an idea of how the students feel about this type of lab in general. From the results, we can see that the students feel that physical labs did help prepare them for a career in networking and helped them to understand the course material, even though it wasn't always very easy to work with.

One question in the survey that students were asked was what they liked about working with physical lab equipment. The responses were open ended so that students were able to freely express their opinions. The student's responses tended to follow a pattern: they liked the opportunity to work hands-on with the equipment that they would be using in the future. One student stated "I enjoy the real hands-on experience. Since in the real world a company isn't going to want you to configure their Packet Tracer for them, we will have to physically work on

routers, switchers, ASAs, APs, IP phones, etc. I understand learning initially on virtual labs, but physical labs will make me the most prepared post-graduation." With physical equipment, the students felt that they were given the most real experience possible in a learning environment.

After revealing what they liked about physical labs, the students were then asked what problems they had while working with the equipment. Students stated many of the same issues: malfunctioning hardware, clashing configurations, and limited availability. The students are frustrated with having enough time to complete their assignments when they are required to clear and reload their configurations onto the equipment at each class period, so as not to interfere with other student's configurations. Frequently, there are times when something on the equipment malfunctions or is not properly configured and students lose precious lab time trying to fix the equipment and then fall behind in their work.

The following questions are about remote labs. Choose the response that most reflects your opinion.				
#	**Answer**	**Average Value**	**Standard Deviation**	**Responses**
1	It was easy to work with.	51.08	25.09	36
2	It supported all of the configurations required for my labs.	64.14	28.24	36
3	It helped me understand course readings and lectures.	55.09	25.80	35
4	It helped me prepare for a career in networking.	54.94	29.66	33

Table 6

Table 6 shows the responses of students when asked to rank on a scale of 1 to 100 how the statements shown in the table reflect their opinion about remote labs. The responses shown in

the table suggest that students do not feel very comfortable working with remote labs. The average values for all four statements were very low, so it is safe to assume that students do not like to use this type of learning environment and would much prefer to use another that is easier to use and better helps to prepare them for their future careers.

After ranking the statements, students were asked what they liked about working with remote labs. The responses generally all said the same thing. Student's liked that they were able to work on the equipment from virtually anywhere. One student stated "The best quality about remote labs, in my eyes, is that they can be worked on at any time. Rather than having to drive somewhere at a specific time, it is possible to do a lab at 3 in the morning if need be." Students tend to have fairly hectic schedules and remote labs provide them with the opportunity to work on their assignments on their own time. They get the experience of using physical hardware and its interfaces without having to be sitting in front of it to do so.

Students were then asked to state what problems they have experienced while working with remote lab equipment. Many students stated that they experienced frequent connectivity issues that disrupted their ability to finish their assignments. If a change needed to be made to the equipment, the students were not able to make it from offsite and had to wait until the next time that they could physically access the equipment. One student stated "It's laggy, it's not realistic, it holds your hand through everything, and I don't learn anything from it." Other students stated that they had a difficult time figuring out a schedule for them to access the equipment when other students weren't trying to use it at the same time.

The following questions are about virtualization software for networking. Choose the response that best reflects your opinion.				
#	Answer	Average Value	Standard Deviation	Responses
1	It was easy to work with.	71.38	22.55	45
2	It supported all of the configurations required for my labs.	63.30	22.43	44
3	It helped me understand course readings and lectures.	74.02	18.94	43
4	It helped me prepare for a career in networking.	72.68	21.94	41

Table 7

The results from questions asked of the students about virtualization software are shown in Table 7. Once again, the students were asked to rank to statements from 1 to 100 on how well they apply to their own opinion. Average results were higher than those of remote labs, but generally lower than those about physical hardware. It shows that students found virtualization software the easiest to work with, but didn't feel that it best prepared them for their future careers.

Students were asked to respond to a question about what they liked about working with simulation software. Generally, students stated that they liked being able to take the assignments with them anywhere and work on it at any time. Being able to set up large-scale networks that the labs might not have the right equipment for is also something that the students liked to have access to. The results all seemed to agree with each other, with one student stating "A lot more work and practice can be done within a smaller footprint; a laptop or home pc can be the whole lab area."

When asked, the students responded with their dislikes about simulation software. They said that they were not able to get the same sort of hands-on experience that they are able to get using either physical hardware or remote labs. Students also had issues with compatibility of the commands on the software, saying "There are usually a few commands not supported in virtualization software like Packet Tracer that are only supported on physical machines." Even though the equipment was able to be taken anywhere, the students still said that they liked having the physical experience more.

If you had to choose between physical hardware, remote labs, or virtualization software, which would you choose to use? Rank the lab types.					
#	**Answer**	**1**	**2**	**3**	**Total Responses**
1	Physical Labs	26	11	3	40
2	Remote Labs	2	9	29	40
3	Virtualization Software	12	20	8	40
	Total	40	40	40	-

Table 8

Table 8 shows the results of the final question of the survey. Students were asked to rank the three different lab types on which they liked best. Physical labs had the most votes for the number one preferred lab type, followed by virtualization software and then remote labs.

Conclusions

The three different options for networking learning environments each have their own benefits and drawbacks. The challenge that instructors are facing to weigh the options of and then choose the best environment for the students is significant. It is important to be able to

provide students with the best possible chance for them to further their education so that they are more likely to succeed in their future careers.

Surveying the students about the different possibilities gives insight into what the students feel is most beneficial to them, and their answers should be taken seriously. The students said that they prefer the use of physical hardware over simulation software or remote labs. Even though there are still issues associated with using physical hardware, the students feel that the real world experience gained through the use and troubleshooting of issues on the physical hardware is what benefits them the most in preparation for their future.

Investing in good physical hardware should be the first thing that networking educators look into doing. Being able to have up-to-date physical hardware for students is important, as well as having a few extras of each type of equipment so that any equipment failures can be easily solved with as little disruption to the work that is being done on the equipment by the students. Despite the cost, using this environment type will be the most rewarding for the student's education and will justify spending the money on the hardware.

In order to ease the use on the physical equipment and to provide students with assignments that do not always have to be completed in a lab environment, the use of simulation software in conjunction with the physical hardware could be beneficial. Assignments could be first built in the simulation software and then transferred or continued on the physical equipment. This way, the students can take and start the assignments before they get to class, and then use the physical equipment to finish the configurations and see how the configurations would work in a real world environment. This saves the students' time in the initial understanding of the concepts while still allowing them the benefits of physical equipment later on.

Students should be able to have access to the best type of education possible. Despite the cost of obtaining and maintaining these systems, the use of physical hardware is what the students prefer and what they believe benefits them the most. Students will tend to be more engaged and open to learning when the experience so closely relates to what they will be doing in their future careers. Being prepared for their future is what the students desire when they begin their schooling, and physical hardware is able to provide them with the real, hands-on environment that accomplishes this.

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Survey Results

1. What is your gender?

#	Answer		Response	%
1	Male		55	86%
2	Female		9	14%
	Total		64	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.14
Variance	0.12
Standard Deviation	0.35
Total Responses	64

2. Networking Experience

#	Question	None	0 - 6 months	6 - 12 months	1 - 2 years	Over 2 years	Total Responses	Mean
1	How long have you studied networking?	2	5	4	17	38	66	4.27

Statistic	How long have you studied networking?
Min Value	1
Max Value	5
Mean	4.27
Variance	1.16
Standard Deviation	1.07
Total Responses	66

3. What forms of technology have you used for networking labs? (Choose all that apply)				
#	Answer		Response	%
1	Physical labs: This is when you have a set of hardware devices which you have direct access. For example, being assigned a set of routers and switches you must configure for a lab.		64	96%
2	Remote Labs: This is when you remotely connect to physical hardware through a network connection.		33	49%
3	Virtualization software: This is software that allows you to create and configure network topologies in a computer. Examples include Packet Tracer, GNS3, and Boson NetSim.		55	82%
4	I have not had to do any networking labs.		3	4%

Statistic	Value
Min Value	1
Max Value	4
Total Responses	67

4. How often have used physical labs in your classes?

#	Answer		Response	%
1	Not At All		0	0%
2	Rarely		1	2%
3	Occasionally		9	19%
4	Frequently		22	47%
5	All the time		15	32%
	Total		**47**	**100%**

Statistic	Value
Min Value	2
Max Value	5
Mean	4.09
Variance	0.60
Standard Deviation	0.78
Total Responses	47

5. The following questions are about physical labs. Choose the response that best reflects your opinion. If you have not worked with physical labs, skip this and the next two questions.

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	It was easy to work with.	29.00	100.00	69.41	19.18	46
2	It supported all of the configurations required for my labs.	30.00	100.00	73.11	22.78	47
3	It helped me understand course readings and lectures.	50.00	100.00	84.93	15.08	46
4	It helped me prepare for a career in networking.	40.00	100.00	86.89	18.54	44

6. What do you like about working with physical lab equipment?
Text Response
I am much more of a hands-on learner, so getting to physically work with the equipment is much more preferable than doing labs with netlabs.
It gives real world practical experience and connects to the lectures in the classroom. It has definetely helped me when working with hardware at my internships that otherwise would not be there if it was virtual or remote.
The real world experience and knowing that this is the type of equipment that I will be using in the real work force.
"good: hands on experience, teamwork with others
Mistakes are made more often with physical lab equipment and allows you to learn from them compared to packet tracers.
Having a partner to work with is nice.
I like the physicality of it. I'm a person who learns hands on so phsyical labs are more benefical to me.
I enjoy the real hands on experience. Since in the real world a company isn't going to want you to configure their packet tracer for them, we will have to physically work on routers, switchers, ASAs, APs, IP phones, etc. I understand learning initially on virtual labs, but physical labs will make me the most prepared post graduation.
hands on experience
Working with physical equipment feels more like a real environment. When something gets accomplished on the physical equipment it's more satisfying than setting up a simulation which is generally much easier.
I think that it gives a sort of real world feel.
It is a good representation of what we would experience in the real world as network technicians
I learn better than just reading about it.
I like the hands on aspect and being able to work with the physical machine.
The hands on experience benefits me personally more so than looking at slides and reading over the material.
Actually working with physical equipment provides a lot more accurate depiction of what it will be like working in the field.
I like the hands on experience, because it helps me to understand concepts better.
Everything in it works accordingly. Real world environment.
It has been very nice learning how to program routers and switches via using actual networking equipment. I've really enjoyed working with the equipment and they have reinforced and helped my understanding of networking.
For example working with routers and switches it helps me picture schemes physically rather than imagining it in my head.
I like the hands-on experience. It is much better than clicking on the computer to connect a wire.
I like how it feels like I'm developing better networking skills. But sometimes I think that the patch panels make it too easy for what it would be like in the real world.
You retain more knowledge if you actually get hands on experience
I like that it gives the student an opportunity to have hands on experience with equipment that they are likely to see in a real world environment. It helps to be able to identifiy different types

of equipment such as routers and switches and the phyical components that can be interchanged. Even though the lab equipment sometime has issues, it is benifical in learning how to troubleshoot things that might not be experienced until entering the field.
Real hands-on experience, actual troubleshooting as opposed to simulated troubleshooting, visual contex for class readings.
It makes it feel more of a real life situation.
It is nice to be able to see and feel exactly what you are working with.
It is actual equipment and not packet tracer. If you actually mess up in a physical lab then you can just delete the switch/router/ect like you can in PT and I like that it makes you work harder.
It's the closest we can get to the real world environment. I would feel much more comfortable in a real business environment if I was proficient in using actual hardware rather than simulators like Paket Tracer.
I just like the fact of getting the experience when working with the lab rather than just reading and going over lectures.
It is more practical than a simulated environment. Such as packets tracer.
As a student with a learning disability, I need to quickly apply any information from lecture or reading material into a hands-on activity. The physical lab equipment allows me to do that.
Working with actual equipment is the most beneficial way to prepare for real life on-the-job scenarios. Although you are limited to smaller scale setups, it's good to be able to get used to physically plugging in cables, consoling in, and troubleshooting layer 1 issues that you might not have to deal with in a virtual environment.
It better prepared me for a real career, where I may be asked to patch a port as well as programming or rebooting equipment. It gives a better feel for how long things should take and physically going through the motions was better for overall memory of the process, so that I can perform the process again without excessive notes.
It emphasizes the real world skills that are needed in a technology based field. Also gives practice to hone these skills.
I prefer hands on
Working with physical equipment.
Physical equipment is the real deal. I do not like working with virtualized equipment that is not virtualized in the real world.
It is more appropriate for real world senarios.
I like that we are working with real world equipment and practicing the skills we are being taught in class.
Hands-on. Real-life scenarios. Experience with machines. Pretty Lights. Real-life troubleshooting (minus the ladders, hands & knees, and sweat).
It is hands on, and it is possible to actually see what you are working with. When first starting, this was much easier to visualize than virtualized networks and servers.

Statistic	Value
Total Responses	42

7. What problems have you had working with physical lab equipment?
Text Response
Every once in a while the lab equipment will have issues such as ports not working, cables being bad, or other small miscellanous problems.
Outdated hardware that does not support current software or configurations that are necessary to complete a lab.
There is not always access to the physical equipment when I need it, and there are times when the hardware is broken or not working.
There is always a problem, something is not updated or switch is old or key is expired there is always something holding a lab back
Typically its my own faults when i have had problems but every once in a while incorrect patching or ISO's have been loaded onto networking equipment.
People not wiping the configuration files causeing the next lab group to spend 10 minutes rebooting the equipment. Some pods are not properly labeled when it comes to VOIP connections.
Equipment not working or not supporting features the lab is asking for. Also, a shortage of equipment can sometimes be a problem.
Since all the physical lab equipment is shared between all the classes, overlapping of classes configurations may cause a problem when "picking up" your lab from the previous class.
Sharing the same equipment with other classes makes it difficult to work efficiently as sometimes the equipment is in use or has been used recently and has configurations on it already
There have been problems with connectivity, especially in the VoIP class.
It does not work all the time since we have to save and reload config files every day and so many students use the same hardware. Often there are unknown passwords on the devices from underclassmen that do not clear their configs. They also take a very long time to clear and load configs, which eat at lab time.
Someone from the class before didn't clear the systems when they where done.
Prior configs still being loaded. Certain hardware not supporting some of the configurations that were needed
Compatibility issues arise more frequently than expected and can stop progress of the labs.
Malfunctioning hardware
Sometimes the instructor is not available to help multiple students at a time, so I can get discouraged sometimes when I don't understand.
Licensing, faulty wires, loading times.
Occasionally a console cable will not work, but generally there have not been many problems associated with the networking equipment.
hardware doesn't support what I'm trying to do. Ex vtp, routing protocols.
I really haven't had that many problems with the physical lab equipment.
Usually the problems from the labs are more to do with the versions being wrong for certain labs, or cables being the wrong type of cable.
Some ports and connections are hard to work
One of the biggest problems is people not knowing how to properly remove their lab configurations or erasing files in flash. Erasing files from flash was especially a problem in the VoIP class where all of the work on call manager is saved locally. I've even seen some student

just power off the router from the back to remove the configurations from ram when that might now always work in a production enviroment when wiping devices. Sometimes there are minor issues with connectivity from the abc switch box and a patch panel might not be punched down right.
Firmware versions not supporting certain configurations from lab manual. Prior classmates not resetting or clearing configurations.
Finding working patch cables have always been an issue and people not deleting their configs.
A lot of times, things do not work the way you want them to.
Sometimes equipment isnt prepared correctly which isnt a huge deal but its just added work
Often times you end up with bad cables. Sometimes the hardware itself is too dated to support certain labs.
There several problems I've had when working with the physical labs. There were problems from when the equipment or configurations wouldn't work correctly and I would have to troubleshoot the problems.
Troubleshooting. Sometimes there are software and version requirements that we do not have access to that are required for certain feature in labs.
The equipment seems faulty at a fundamental level. Because my computer doesn't have a working COM port, I have to chase down a USB converter for a console cable almost daily. Due to a faulty computer network card, I failed a midterm practical. Due to a failing switch-port, my group in one of my classes is now four weeks behind schedule. These are only a few of the numerous problems I have had to experience with computer tech equipment.
The biggest issue that is run into is when people leave their configurations on the equipment. However, this really isn't too big of a deal and actually gives students experience erasing configs and VLAN databases. There are of course times when things do not work as expected, but once again, it gives students practice with troubleshooting. Since such a large part of the CCNA deals with troubleshooting, these frustrating scenarios actually offer great practice for the big exam.
The only issues I had were revolved around shared equipment. When equipment was shared among multiple classes, students may forget to erase configs or the cables may be broken and need repair or replacement. This is why I had to start bringing in cables for some of my classes.
Connections being miswired. Hardware that was needed for labs was not in the racks. Others being lazy with resetting configs or other small but annoying tasks.
People not erasing running configs from previous classes
Hard to work with do to disability.
The main issue is equipment availability.
There are issues that we have not discussed in class. This leaves the professors needing to solve problems whil the students sit there.
Cables failing
Is not always compatible with the content being taught. Updates Updates Updates. Is not always advanced enough for the network-design-plan.
The main issue with using a physical lab is that it is shared, meaning any extensive project must be torn down and completely rebuilt for every session.

Statistic	Value
Total Responses	41

8. The following questions are about remote labs. Choose the response that best reflects your opinion. If you have not worked with remote labs, skip this and the next two questions.

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	It was easy to work with.	0.00	100.00	51.08	25.09	36
2	It supported all of the configurations required for my labs.	0.00	100.00	64.14	28.24	36
3	It helped me understand course readings and lectures.	0.00	100.00	55.09	25.80	35
4	It helped me prepare for a career in networking.	0.00	100.00	54.94	29.66	33

9. What do you like about working with remote labs?
Text Response
I like the convience of working on them whenever I want and from home.
They decrease set up time in turn allocating more time for actual configuration.
Easier with less problems
I can do the lab from anywhere.
Convienient. Being able to access the labs from home makes for less time in the lab and on campus.
As stated previously, I really enjoy the hands on experience. Remote networking is very large in the field as it allows technicians to work from home/office without having to travel to site. This saves time and money for both parties involved. This is a great skill to learn and have before working your first job.
They are more similar to real world situations because most of the time in the work place you do not connect directly to the device.
It makes it easier to do homework instead of coming in to do it.
The ability to work on labs without having to be at the machine physically, such as at home.
It's like an interactive lab manual (I'm assuming labs like MOAC?)
I like that I can connect to a computer in the same network and control or access it without physically being at that computer.
Provides different views rather than being physically connected. Ex clustering servers, ssh, etc
I've never had to do a remote lab.
The benefits of real hardware without necessarily needing access to the physical equipment.
I like that they can be accesses anywhere.
They are easy to work with.
It simulates skills you need for the networking world (telnet, ssh). Similar to working with physical hardware that's located right next to you.
Typically the environments have already been prepared for us. So in that sense, it eliminates headaches. But it also is nice not having to be physically at the machine.
I enjoy working with remote labs because it takes away the lab environment. I can be out drinking coffee, or out at dinner with family, and even in those instances I can access my remote labs. This ultimately takes away all of the problems with fighting for computer pods with the other classes.
It gives a lot more options to work with and you can do many different applications than just the physical labs offer.
Availability
We have only done one, but I really didn't like it.
Still deals with equipment. Gives more opportunities for troubleshooting when off-site.
The best quality about remote labs, in my eyes, is that they can be worked on at any time. Rather than having to drive somewhere at a specific time, it is possible to do a lab at 3 in the morning if need be.

Statistic	Value
Total Responses	24

10. What problems have you had working with remote labs?
Text Response
I have been assigned two netlabs assignments so far. The first time it took several days before I was finally able to get in, and even then my partner could not access and so I had to complete the lab by myself. The second lab I am still yet to complete. It was assigned over a week ago but myself and my classmates still do not have access to netlabs and so we cannot complete the assignment.
Simply them not working properly due to several variables.
Frustrating and person needs to know and work with the program to understand it
Connection issues and slowness on the network and some delay issues.
Having to use Ball State VPN to gain access off campus.
Haven't had any in the program.
sometimes it wouldn't remote in
They can be similarly difficult to work with like the physical labs except with the added difficulty of connecting remotely to the device.
Really have not had any problems yet.
If I am unable to reach the lab in the first place because of connectivity issues it does not help any more than a physical lab would.
It's laggy, it's not realistic, it holds your hand through everything, I don't learn anything from it.
Some don't have full functionality yet but they'll get better
I've never had to do a remote lab.
Not having physical access to equipment.
Some of the configs are not supported through Packet tracer.
They never give out errors to learn from/
It can be frustrating when you feel the need to make a change to the equipment and cannot do so because the equipment is inaccessible.
Actually getting connected to the machine has been a hassle.
The only problem I have working with remote labs is equipment failures or misunderstandings. One of my classes is using an ESX server, allowing us to access servers from anywhere on the internet. Due to some misunderstandings with the 466 class, the equipment failed, leaving us without access to our servers, and therefor putting us a couple weeks or more behind in our class.
Software licensing and teachers not knowing passwords.
They are always broken
Not real world situations
Connection dropping, time constraints,
Troubleshooting. Equipment going down. Not being able to connect. Crashes. Ping irregularities.
The issue with remote labs is that it is hard to visualize what one is working with.

Statistic	Value
Total Responses	25

11. The following questions are about using virtualization software for networking labs. Choose the response that best reflects your opinion. If you have not worked with virtualized software for networking labs, skip this and the next two questions.

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	It was easy to work with.	0.00	100.00	71.38	22.55	45
2	It supported all of the configurations required for my labs.	10.00	100.00	63.30	22.43	44
3	It helped me understand course readings and lectures.	31.00	100.00	74.02	18.94	43
4	It helped me prepare for a career in networking.	14.00	100.00	72.68	21.94	41

12. What do you like about working with virtualization software for networking labs?
Text Response
You can leave them and come back to them at anytime and allows for more time configuring because there is no setup or teardown of physical equipment.
I could take it anywhere and work on things that weren't even class related in my spare time.
Easy with less problems that can arise, faster than physical
I can perform them at home.
That i could virtualize any OS i needed to work with and didnt have to worry about messing up the host OS.
The ability to try new things and make mistakes and be able to start again.
I believe they are essential for beginning level learning for networking, but shouldn't be used in the higher level classes.
you can have all machines on one computer
Everything generally works in virtualization software (unless it isn't supported). The interface makes it easy to remember commands and configurations as well.
I like working with these because you can setup many different networks and configure them as you please. I feel like these labs are much more reliable because they almost always work as they should.
They are easier to work with than physical hardware that you have to reload configs on constantly. It is easier to access when it is a program on a home computer and you don't have to go into the labs to do homework.
There is really nothing I like about it.
I like being able to work on my labs whenever I have time and being able to see a phusical layout of the topology
The ability to revert back to previous snapshots if something major breaks makes for an easy restart.
Setting up VM's and using vmware utilities is a skill that is sought after in the professional environment. I feel like I'm learning something practical. Snapshots.
I like the aspect of creating computers and running multiple softwares on one computer.
It's easy and shows every process being made. Fast fowarding through time really helps with loading times of running configs.
Working with programs such as packet tracer vastly helped my learn how to design, create, and learn how networks are formed and maintained.
Virtualization is the next best thing so learning it will only help in the future.
I like that you can use it anytime. You don't have to be physically there in order to do the lab.
Packet tracer usually makes labs seem easier than what they are physically.
I enjoy using the virtual labs, but they don't provide the same feel for experience that the physical equipment did. It was nice to be able to fast forward time in order to avoid waiting. The software is especially great for quickly designing a network for testing or troubleshooting a specific problem.
Tons of options for configuring networks. No need for expensive equipment. Ease of access to configuration terminals and interfaces.
I also like they can be accessed anywhere.
It is easy to work with.

I like working in PT because it is easy to fix a problem
It's easier to see a topology from a logical perspective and break it down based on a hierarchical model.
No hassle physically. Eliminates time working with the physical layer. Also work can be taken home.
I enjoyed working with visualization software for networking labs because I invested in the equipment that could handle the resource cost. Both in networking and systems administration, these had the fewest problems.
Packet Tracer is a great tool for setting up larger-scaled scenarios and learning concepts from home. I honestly use it all of the time since I do not have my own physical equipment setup.
Virtual labs can be completed anywhere at anytime. Packet tracer is an excellent example of the anywhere/anytime point, especially when an internet connection is not possible. Netlabs works well enough that the equipment can be full featured and does not require that one be physically present in the lab.
Most often things work exactly the way they are supposed to. It allows for easy testing of configurations before implementing them into a physical configuration.
Being able to do everything at home.
We have control over the software
They are very easy to do at any time.
I like being able to make actual networks in the virtual environment as well as being able to work with a lot of different equipment items.
Typically loads correctly no matter what. Easy to troubleshoot. Easy to load.
A lot more work and practice can be done within a smaller footprint; a laptop or home pc can be the whole lab area (packet tracer is an excellent example).

Statistic	Value
Total Responses	38

13. What problems have you had working with virtualization software for networking labs?
Text Response
Just the limitations with virtualization.
Not all of the configurations are supported by Packet Tracer that are supported on physical hardware.
Not as realistic has physical, computer problems
Sometimes the virtualized labs don't let you perform some of the things learned in class.
nothing
Licensing of VMWare products or other software. Physical limitations of host hardware not allowing for efficient running of VMs.
They don't give real hands on experience. Packet tracer is also very buggy and involves many unneeded problems.
Sometimes the limitations of the programs make it difficult to accomplish what I try to do if the scope of the project is too large or unsupported
I have not experienced any real major problems working with the virtualization software.
They are not a real world setting since they are a simulation of the environment. They do not support all the features required in higher level networking classes. They can be buggy and PacketTracer does not work well with Windows 8 and is not available for OSX.
If I had a problem I had to email the instructor and wait until I got a replay back from them.
Sometimes the virtual labs crash or don't support certain configurations
Sometimes compatibility issues can slow progress or issues with licensing not allowing certain required features.
Resource dependent
Not configured to do everything the switches can actually do.
In my upper level classes, some of the advanced protocols are not included, so most of the time, we would do an equipment lab that would support the configurations necessary to complete the lab.
None I can think of.
There are usually a few commands not supported in virtualization software like Packet Tracer that are only supported on physical machines.
In the past i've had the software crash unexpectedly before I was able to save. There have also been issues where packet tracer doesn't support a feature that the physical equipment would.
Troubleshooting is simulated. Sometimes uncontrollable problems existed and could not be fixed even though all commands and interfaces were configured properly.
Some configs can not go thorugh packet tracer.
None
Ive had problems with PT not supporting a certain protocol or understanding certain syntax
Many commands that can be issued on hardware are not supported through virtualization software.
Sometimes features are not supported in a virtualized environment. For example. Ether channeling.
The only problem with virtual labs, such as packet tracer, is limitation as to what commands were supported. There were select differences from the Cisco switches on packet tracer, and their

counterparts in the labs. This not allowing a simple show run copy paste to transfer configs. There has also been limitations as far as supported commands in the switches and routers within packet tracer.
The problem with Packet Tracer is the fact that it does not support some protocols. I have run into issues with HSRP not working and GLBP is not an option. There are a few others that are not supported as well. I don't have much experience with GNS3, but it seems to be superior since it doesn't have the same limitations as Packet Tracer. However, I still feel like the physical labs offer the best practice.
Usually, the virtualized platform cannot emulate all features of the real equipment. Packet tracer was a huge offender in this category. Packet tracer also had glitches that required techniques that would not be OK to use on the job.
The labs were just step by step and it did not go beyond the instructions. Many times it was unclear why we were doing it because we just were completing the lab to get credit.
Does not support all configurations.
Does not present real world problems
They do not support all the software required.
None that have not been due to my own mistakes.
No hands-on. Does not apply to real-life applications as much. Updates Updates Updates. Not always compatible.
It is hard

Statistic	Value
Total Responses	35

14. If you had to choose between physical labs, remote labs, or virtualization software, which would you choose to use? Rank order the lab types.

#	Answer	1	2	3	Total Responses
1	Physical Labs	26	11	3	40
2	Remote Labs	2	9	29	40
3	Virtualization Software	12	20	8	40
	Total	**40**	**40**	**40**	-

Statistic	Physical Labs	Remote Labs	Virtualization Software
Min Value	1	1	1
Max Value	3	3	3
Mean	1.43	2.68	1.90
Variance	0.40	0.33	0.50
Standard Deviation	0.64	0.57	0.71
Total Responses	40	40	40

Student Symposium Poster

Student Preferences in Networking Lab Environments

Chelsea Schultz

Faculty Mentor: David Hua

Introduction

- Students are learning new technology and information and need a way to apply their learning
- Data networking is the foundation on which other information technologies are built
- It is difficult to provide an appropriate environment for learning to the students mostly based on cost.
- Students generally use three types of environments to learn networking: physical equipment, remote lab solutions, and virtualization software
- Each type of environment has its own benefits and drawbacks including time and cost
- Hands-on lab activities are known to be essential in teaching networking
- The applied experiences reinforce the theoretical framework that the students learn in the classroom
- Initial belief is that students and instructors prefer working with physical hardware, but use virtualization software due to cost restraints

Objectives

- Investigate preferences of students and instructors in data networking classes of learning environments
- Collect user feedback
- Develop and present recommendations on how to keep students engaged in networking education
- Create an article to explain the results of the survey and recommendations

Methods

- Subjects
  - Students and instructors using the Cisco Networking Academy in the United States
  - Flyer sent through email attachment will describe the study and provide link to survey
- Data Gathering
  - Qualtrics Survey

Conclusions

Students were asked to rank the types of networking lab environments by their preference, and the students followed the initial hypothesis. Physical labs were ranked first among the students, followed by virtualization software, and then remote labs.

#	Answer	# 1	# 2	# 3	Total Responses
1	Physical Labs	24	11	3	38
2	Remote Labs	3	8	28	39
3	Virtualization Software	12	19	7	38
	Total	39	38	38	

When asked to explain their preferences, students answered that they prefer to have the real world experience that using physical hardware provides, but are frustrated with the equipment's availability and functionality. Virtualization software is more accessible to students but does not always support all configurations. Remote labs have more accessibility convenience than physical hardware, but students experience a lag or connectivity issues.

Survey Questions

What forms of Technology have you used for Networking Labs?

#	Answer	Response	%
1	Physical labs: This is when you have a actual hardware devices which you have a direct access. For example, being assigned a pair of routers and switches you must configure for a lab.	44	84%
2	Remote Labs: This is when you remotely connects physical hardware through a network connection.	34	65%
3	Virtualization software: This is software that allows you to create and configure network ecologies in a computer. Examples include Packet Tracer, GNS3, and Boson NetSim.	39	75%
4	I have not had to do any networking labs.	3	6%

Physical Labs: Choose the response that best reflects your opinion

#	Answer	Min Value	Max Value	Average	Responses
1	It was easy to work with.	20.00	100.00	86.67	43
2	It supported all of the configurations required for my labs.	30.00	100.00	79.55	44
3	It helped me understand course readings and lectures.	20.00	100.00	84.61	43
4	It helped me prepare for a career in networking.	40.00	100.00	87.20	41

Remote Labs: Choose the response that best reflects your opinion

#	Answer	Min Value	Max Value	Average	Responses
1	It was easy to work with.	0.00	100.00	81.06	33
2	It supported all of the configurations required for my labs.	0.00	100.00	84.67	33
3	It helped me understand course readings and lectures.	0.00	100.00	83.91	33
4	It helped me prepare for a career in networking.	0.00	100.00	83.70	30

Virtualization Software: Choose the response that best reflects your opinion.

#	Answer	Min Value	Max Value	Average	Responses
1	It was easy to work with.	0.00	100.00	71.00	43
2	It supported all of the configurations required for my labs.	34.00	100.00	84.89	41
3	It helped me understand course readings and lectures.	34.00	100.00	79.10	40
4	It helped me prepare for a career in networking.	14.00	100.00	79.33	39